PHYSICAL FITNESS OF U. S. NAVY SPECIAL FORCES TEAM MEMBERS AND TRAINEES

M. B. BECKETT
H. W. GOFORTH
J. A. HODGDON

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NAVAL HEALTH RESEARCH CENTER
P.O. BOX 85122
SAN DIEGO, CALIFORNIA 92138

NAVAL MEDICAL RESEARCH AND DEVELOPMENT COMMAND
BETHESDA, MARYLAND

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Marcie B. Beckett

Hal W. Goforth

James A. Hodgdon

Operational Performance Programs

Naval Health Research Center

P. O. Box 85122

San Diego, CA 92138-9174

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Summary

Candidates for U. S. Navy Special Warfare Sea Air Land (SEAL) teams undergo vigorous training at Basic Underwater Demolition/SEAL (BUD/S) school. Recently, some question has arisen as to whether BUD/S graduates are adequately prepared to become active SEAL team members (SEALs). This study was undertaken to compare BUD/S graduates with SEALs with respect to their physical condition and capacities.

Thirty-nine BUD/S graduates and 48 SEALs were characterized in terms of physical fitness, physique and cold pressor response. BUD/S graduates were found to be leaner than SEALs, to have slightly less muscle strength and anaerobic power, but greater muscle endurance and aerobic capacity. Both groups had similar responses to a cold pressor test.

These differences undoubtedly reflect differences between the training and operational environments, and some consideration must be given to whether the training program needs to be modified to change physical fitness outcomes. It should be recognized, however, that these differences in physical fitness are relatively small, and BUD/S graduates appear sufficiently prepared to join the ranks of operational SEALs.

Introduction

Navy Special Warfare personnel, such as members of Sea Air Land (SEAL) teams, perform jobs requiring a high level of physical endurance and strength (Robertson & Trent, 1984). In preparation for this demanding occupation, trainees at the Basic Underwater Demolition/SEAL (BUD/S) school undergo a six-month training regimen that includes extremely strenuous physical conditioning (McDonald, Norton & Hodgdon, 1988; Robertson & Trent, 1984). As might be expected, high attrition has been a problem for this intense training program. So much of a problem, that several investigators have attempted to identify psychological and physical predictors of success or failure in BUD/S training (Doherty, Trent & Bretton, 1981; Robertson & Trent, 1984; Ryman & Biersner, 1975; McDonald, et al, 1988).

As a result of both previous and ongoing studies, some training program modifications have been recommended and implemented. With the advent of these changes, the question has arisen: "Are BUD/S graduates adequately prepared to become active SEAL team members?" In an attempt to answer this question, this study was undertaken to compare the physical fitness, cold pressor response, hematological and psychological attributes of BUD/S graduates with those of operational Navy Special Warfare personnel.

This report is limited to the comparison of physical fitness and cold response data. Other reports will deal with the hematological and psychological comparisons.

Methods

In the present study, measurements were taken on students graduating from BUD/S training and on active Navy Special Warfare personnel in an effort to characterize and compare personnel with respect to physique, muscle strength, power and endurance, cardiovascular capacity and cold pressor response.

Subjects

Participants in this study were 39 BUD/S graduates and 48 members of

Navy Special Warfare teams (SEALs). Table 1 provides a breakdown of the group by BUD/S class or Special Warfare team. The SEALs group included members of both a SEAL Delivery Vehicle (SDV) team and a SEAL team. Testing of SEALs occurred during the time period of March, 1987 through January, 1988. BUD/S testing was conducted from March through July, 1988. BUD/S graduates were tested during the three weeks prior to their graduation. Each subject was briefed upon the nature of the study, attendant risks and benefits, and gave voluntary consent prior to testing.

TABLE 1. Subject affiliation.

Origin		n
BUD/S		
Class 149		10
150		10
151		9
152		10
SEALs		
SEAL Team 5,	platoon C	10
	platoon F	8
	platoon H	8
SDV Team 1,	platoon A	6
	platoon B	11
	platoon C	5

Testing Sequence

Each subject underwent three testing sessions, on non-consecutive days. Tests were administered in order (except as noted in Session 1) as follows:

Session 1: Anthropometry, vertical jump, handgrip (in any order). Sit-ups, push-ups, pull-ups, timed 1.5-mile run.

Session 2: Blood lactate after cycling, bench press, cold pressor response, isokinetic leg strength.

Session 3: Resting EKG, Wingate, lifting capacity, sit-reach, incremental treadmill (maximal).

This sequence was altered during the testing of the last two BUD/S classes when the tests of "Session 3" were administered one week prior to the tests of "Session 2."

Vital Signs and Physique Assessment

Resting Heart Rate and Blood Pressure. At the completion of a 12-lead resting EKG (VS4S, Cambridge Instrument Co., Ossining, NY), heart rate (bpm) of the supine subject was recorded from digital display. The subject was then seated and systolic and diastolic blood pressures (mmHg) were assessed on the left arm via auscultation.

Anthropometry. Body weight was measured to the nearest 0.25 lb. and height to the nearest 0.25 in. on a beam balance scale (Health-O-Meter, Continental Scale Corp., Chicago, IL). Four body circumferences, eight skinfolds and two bone diameters were assessed. Two to three measurements were taken at each site, with the final value for each site being calculated as the average of all measurements at that site.

Body circumferences were measured to the nearest 0.1 cm with a fiberglass tape. Circumferences of the neck, abdomen and calf were assessed according to procedures described by Beckett and Hodgdon (1984). Flexed-biceps girth was taken as described by Carter (1982).

A Harpenden caliper (British Indicators, Ltd., St. Albans, Herts, England) was used to assess skinfold thicknesses to the nearest 0.1 mm. Measurements were taken at the biceps, triceps, subscapular, supraspinale, and thigh sites using the methods reported by Beckett and Hodgdon (1984). Chin, iliac crest, and medial calf skinfolds were measured as described by Behnke and Wilmore (1974), Durnin and Womersley (1974), and Carter (1982), respectively. All eight skinfolds were summed to provide an indicator of relative fatness.

Bone diameters were measured to the nearest 0.5 mm with a modified sliding vernier caliper (Scherr Tumico). Bi-epicondylar diameters of the humerus (elbow) and femur (knee) were assessed using the technique of Carter (1982).

An estimate of percent body fat was calculated from height and neck and abdomen circumferences according to an equation developed by Hodgdon and Beckett (1984) and currently used by the Navy in its Physical Readiness Program (CNO, 1986). The fat-free weight of the body was derived from percent body fat and body weight.

In order to assess overall physique, the Heath-Carter somatotype (Carter, 1980) was calculated from triceps, subscapular, supraspinale and calf skinfolds, biceps and calf girths, elbow and knee diameters, height and weight. The three somatotype components - endomorphy, mesomorphy and ectomorphy - reflect the body's relative fatness, musculoskeletal development and linearity, respectively. The endomorphic rating was calculated using an adjustment for height.

Muscle Strength Tests

Handgrip. Both right and left handgrip isometric strengths were measured to the nearest kg with a dynamometer adjusted to hand size (Asimow Engineering Co., Los Angeles, CA). Trials with right and left hands were alternated at 15-sec intervals until three scores for each hand were obtained. Final scores were the highest values achieved with each hand.

Bench Press. Bench press was performed on a multi-station weight machine (Universal Gym Equipment Inc., Fresno, CA). All subjects were required to use a standardized lifting form, which included shoulders and hips in contact with the bench, feet on floor, and no further adjustment in body position once the lift had commenced. After nine warm-up repetitions at three submaximal loads (determined as a percentage of body weight), single repetitions were performed at progressively greater loads in order to determine 1-repetition maximum (1-RM) in approximately three trials. One minute of rest was taken between trials and 1-RM was recorded to the nearest

15 lb. (one weight plate increment). If the entire weight stack (270 lb.) was lifted, additional weight (in multiples of 10-lb. increments) was added until 1-RM was demonstrated.

Leg Extension/Flexion Torque. A CYBEX II isokinetic testing apparatus (CYBEX, Ronkonkoma, NY) was used to assess knee extension/flexion strength. The subject was seated with arms, torso and legs stabilized so as to restrict body movement to knee extension and flexion alone. Pretest warm-up consisted of three maximal repetitions at 120°/sec and three at 90°/sec. The leg was then "weighed" by setting the dynamometer shaft to horizontal (with leg attached and knee fully extended) and recording the torque generated by the totally relaxed leg. After a brief rest, the test commenced and the subject performed 15 maximal repetitions at 60°/sec. During the test, dynamometer signals were input to a MINC-23 computer (Digital Equipment Corp., Marlboro, MA). In-house developed software was used to count strokes and calculate peak torque (Nm). In these calculations, an adjustment for weight of the leg was made so that its contribution to flexion torque and its detraction from extension torque were eliminated. A flexor/extensor ratio was calculated as peak flexion torque divided by peak extension torque.

Lifting Capacity. Lifting capacity was assessed with an Incremental Lift Machine (ILM) (McDaniel, Kendis & Madole, 1980). Both the Air Force and the Army have used the ILM for physical fitness testing at the Military Entrance Processing Stations. The ILM consists of an adjustable weight stack (40 to 200 lb. in 10-lb. increments), a lift bar, and two upright tracks that guide the weights during a lift. With hands approximately shoulder width apart and palms facing the body, the subject lifted the bar from its resting height of 28 cm to a final height of 152 cm. A strict, straight-back, bent-knee lifting form was used by all subjects. Four warm-up lifts at submaximal loads were followed by a 1-min rest. At that point single lifts at increasing loads were alternated with 1-min rest periods until maximal lift was achieved. Increments were adjusted in an attempt to reach a maximal lift in approximately three trials. If the entire weight stack was lifted, additional weight was added in multiples of 10-lb. increments until maximal lift was achieved.

Explosive Muscle Power Test

Explosive muscle power, the ability of the muscle to generate a large force in a very brief period of time, was assessed with a vertical jump. Jump distance was measured to the nearest 0.5 in. using a VERTEC apparatus (Questek Corp., Northridge, CA). Initially, the subject stood with his feet together and one-arm reaching height was determined on the device and recorded. The jump began from a two-legged crouching start and ended with a one-arm reach to deflect the highest measurement vane directly overhead. The difference between jump height and standing reach height was calculated as jump distance and the best of the three trials was the final score.

Anaerobic Power Test

The Wingate anaerobic power test (Bar-Or, 1987) was performed on a mechanically braked bicycle ergometer (Model 864, Monark, Varburg, Sweden). Pedaling rate (rpm) was monitored via a cable-driven DC generator interfaced with a computer (Model 9825B, Hewlett-Packard, Fort Collins, CO). Pre-test warm-up consisted of pedaling for three minutes at 60 rpm and 1.5 kp, with three 5-sec sprints occurring during the second minute. After a brief rest, the subject pedaled against no load at gradually increasing speed. When 150 rpm was reached, the computer signaled and a weighted basket was manually released to provide a constant resistance (0.095 kp per kg body weight) against which the subject pedaled maximally for 30 sec. In-house software calculated the highest average power (W) at any 5-sec period and the average power over the entire 30 sec.

Muscle Endurance Tests

Sit-ups. Abdominal and thigh muscle endurance was assessed via a sit-up test. This test was administered according to procedures described in the Navy's Physical Readiness Test (PRT) instruction, OPNAVINST 6110.1C (CNO, 1986). The number of correct sit-ups completed in 2 minutes was the final score.

Push-ups. Chest and triceps muscle endurance was measured with push-ups. This test was also given according to PRT guidelines. The number of correct push-ups completed in 2 minutes was the final score.

Pull-ups. A pull-up test was used as an indicator of biceps and latissimus dorsi muscle endurance. Maximum number of continuous, supinated pull-ups was recorded. Strictly enforced guidelines required full range-of-motion and prohibited swinging, kicking and resting.

Leg Extension/Flexion Work. During the CYBEX II isokinetic leg strength test described previously, work capacity of the leg was assessed. In-house developed computer software analyzed incoming torque and position angle signals to calculate total extension and flexion work (J) performed during the 15-repetition test.

Blood Lactate After Cycling. This submaximal bicycle test was developed by Jacobs, Sjödin and Schéle (1983). Subjects rode a stationary cycle ergometer (Monark, Sweden) at a power output of 200 W (60 rpm, 3.4 kp load) for 6 min. Blood was then obtained from a finger tip, spun down, and plasma lactate concentration (mmol/L) measured with an automatic enzymatic analyzer (Model 27, Yellow Springs Instrument Co., Inc., Yellow Springs, OH).

Flexibility Test

The PRT sit-reach was modified in order to quantify hamstring and low back flexibility. Prior to the test, subjects were given time to stretch their legs and backs. The subject sat on the deck with knees extended, feet 15 cm apart, and soles flush against a vertical board. A horizontal scale was set at toe level and reach length beyond or short of toes was measured. Subjects reached toward/past toes as far as they could in three slow, progressive attempts. The last reach was held for 1 sec and recorded to the nearest 0.5 cm.

Aerobic Capacity Tests

Incremental Treadmill. Aerobic (cardiovascular) capacity was assessed during a continuous, incremental treadmill test. Subjects walked on the level treadmill (Model 18-60, Quinton Instruments, Seattle, WA) for 1 min at 3 mph and then ran for 5 min at 6 mph. Each minute thereafter the treadmill speed was increased by 0.5 mph until 10 mph was attained. Following that, the 10 mph speed was maintained, and the treadmill was elevated 1% each minute until maximal volitional exhaustion was reached.

Rate of oxygen consumption was monitored continuously via open-circuit spirometry. As the subject breathed through a 2-way valve (Model 2700, Hans Rudolph, Kansas City, MO), expired gas was analyzed for fractional oxygen and carbon dioxide (Models S-3A and CD-3A, Applied Electrochemistry, Pittsburgh, PA). Inspired air flow was measured with a pneumotachometer (Model 3800, Hans Rudolph, Kansas City, MO) and pressure transducer (Model MP45, Validyne, Northridge, CA). Ambient vapor pressure and temperature were assessed with a Dew Point Hygrometer (Model 91, Yellow Springs Instrument Co., Yellow Springs, OH). Heart rate was measured with a single-lead EKG (Model VS4, Cambridge Instrument Co., Ossining, NY). Instruments were interfaced with a MINC-23 computer (Digital Equipment Corp., Marlboro, MA) for on-line averaging, computation and output of results for each 15-sec interval. At test completion, peak values for oxygen consumption (ml/kg·min), ventilation (l/min) and heart rate (bpm) were calculated as the average of the highest four consecutive 15-sec values.

Timed Run. A 1.5-mile timed run was administered as per the Navy's PRT instruction. Six to 10 subjects ran at a time on an asphalt course (3.5 laps), and run time was recorded to the nearest second.

Cold Pressor Response Test

A cold pressor test, modified from that described by Hines and Brown (1936), was administered. Blood pressure (left arm) was monitored via auscultation and heart rate via a single-lead EKG with digital display

(EK-8, Burdick Corp., Milton, WI). With the subject seated, blood pressure (mmHg) and heart rate (bpm) were measured every 30 sec until stable readings were obtained. The right hand was then immersed to the wrist in 4°C water. During the 5-min immersion period, the water was stirred continuously and the water temperature maintained at 4°C (± 1°C). Blood pressure and heart rate were recorded every 30 sec during the test.

Responses to the cold pressor test were analyzed in the following manner: Baseline heart rate and blood pressure were taken from the average of the last two pretest readings or from the scores obtained in conjunction with the resting EKG, whichever was lowest. Peak heart rate and blood pressure responses were identified as the largest readings obtained during the 5-min test. Areas under the cold pressor response curve were calculated for heart rate and systolic and diastolic blood pressures. Area under the curve was estimated as the sum of the areas of consecutive rectangles. Dimensions of the rectangles were defined by the difference between the average of two consecutive measurements and the baseline value as one axis and the time interval between consecutive measurements (30 sec) as the other.

In addition, peak blood pressure during the first minute (1-min peak) was identified, and 1-min rise was calculated as the difference between baseline and 1-min peak. The originators of the cold pressor test, Hines & Brown (1936), used these two parameters to categorize individuals as normal responders or hyperreactors. Hyperreactors were those subjects who showed either 1) an excessive 1-min rise in systolic or diastolic blood pressure (>22 mmHg); or 2) an excessive 1-min peak systolic or diastolic blood pressure (>145 or >100 mmHg, respectively). This classification scheme was implemented in this study in an effort to categorize cold response.

Statistical Analysis

Analysis of data was performed on a VAX 11-780 computer using SPSS^X (SPSS Inc., 1986). Significance was accepted when $p<.05$. The t-test procedure was used to detect differences between groups and chi-square analysis was applied to detect differences in cold pressor response categories.

Results and Discussion

Descriptive data and results of t-tests are presented in Tables 2 through 6. Sample size varies because some subjects vere not able to attend all testing sessions.

TABLE 2. Participant characteristics, body composition and physique.

	BUD/S (n=39)		SEALs (n=48)	
Attribute	Mean	S.D.	Mean	S.D.
Age (yrs)	22.2*	2.4	25.9	4.4
Blood pressure, sitting (mmHg)[a]				
systolic	116.4	10.8	116.3	13.1
diastolic	75.2	6.7	77.6	9.5
Heart rate, supine (bpm)[a]	61.2	10.7	64.0	8.4
Weight (lbs)	168.1	12.4	174.1	17.5
Height (in)	69.9	2.5	69.7	2.0
Body Composition/Physique				
% Body fat	10.4*	2.2	14.2	3.4
Fat-free weight (lbs)	150.4	10.6	149.0	11.9
Sum of 8 skinfolds (mm)	60.1*	8.9	73.7	19.8
Endomorphy rating	2.1*	0.4	2.7	0.8
Mesomorphy rating	5.8	0.8	5.9	0.9
Ectomorphy rating	2.1*	0.8	1.8	0.8

* Significant ($p<.05$) difference between groups.
[a] BUD/S (n = 36), SEALs (n = 32).

Comparison of physique and body composition scores in Table 2 reveals BUD/S graduates are leaner (i.e., less % body fat and skinfold sum) but just as muscular (i.e., equivalent fat-free weight and mesomorphy) as SEALs.

Figure 1 is a somatochart that displays mean somatotypes for both groups and for various male Olympic athletes, as well as male non-athletes (de Garay, Levine & Carter, 1974). The three axes of the somatochart represent the three physique components --- endomorphy, mesomorphy and ectomorphy. The closer a point is plotted to the labeled end of an axis, the stronger is that physique component. This somatochart reveals that BUD/S and SEAL groups are plotted fairly high along the mesomorphic axis, and therefore have more musculoskeletal development (mesomorphy) than reference males and many of the sports groups. SEALs are slightly fatter (more endomorphic) and less linear (ectomorphic) than BUD/S and many of the sports groups. In terms of average physique, both BUD/S and SEALs bear closer resemblance to Olympic athletes than to non-athletic men.

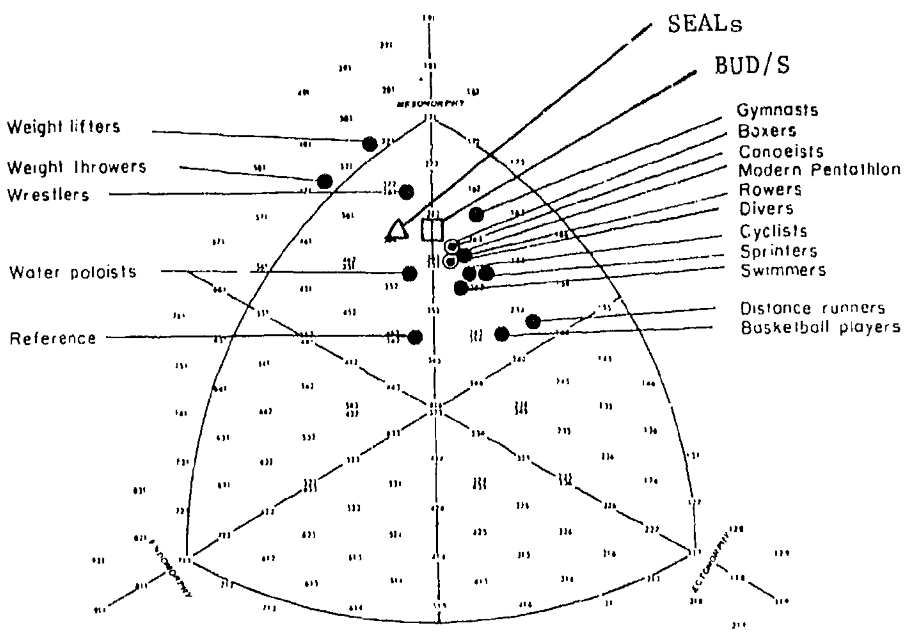

Figure 1. Mean somatotypes for SEALs, BUD/S, various male Olympic sports groups and reference (non-athlete) males. (Modified from de Garay, Levine & Carter, 1974)

TABLE 3. Muscle strength/power and anaerobic power.

Attribute	BUD/S n	BUD/S Mean	BUD/S S.D.	SEALs n	SEALs Mean	SEALs S.D.
Muscle Strength						
Handgrip, right (kg)	39	43.2	5.7	48	45.8	7.2
Handgrip, left (kg)	39	42.2*	5.8	48	45.7	6.6
Bench press (lbs)	36	201.0	32.6	39	214.9	43.3
Leg extension torque (Nm)	35	198.8*	25.8	39	217.1	39.5
Leg flexion torque (Nm)	35	138.9	17.8	39	148.1	24.8
Flexor/extensor ratio	35	0.70	0.09	39	0.69	0.09
Lifting capacity (lbs)	36	152.8*	21.1	31	168.9	29.5
Explosive Muscle Power						
Vertical jump (in)	39	18.4*	1.8	44	19.4	2.6
Anaerobic Power						
5-sec power (W)	36	895.4*	95.4	32	962.1	146.3
Average power (W)	36	694.2	72.6	32	700.0	89.3

* Significant ($p<.05$) difference between groups.

Higher scores in several of the muscle strength and power events (see Table 3) suggest SEALs may possess somewhat greater capacity for exerting large muscular forces. These findings are consistent with physical training information gathered via a detailed Physical Activity Questionnaire administered to the subjects as part of the overall research project. According to questionnaire responses, only one BUD/S graduate trained regularly ($\geq$ 3 days/week) with weights, while 41% of SEALs did so.

Anaerobic power results from the Wingate test were mixed -- BUD/S and SEALs had equivalent average power, but SEAL peak (5-sec) power was greater. Power scores from this test have been shown to reflect the capacity for doing high intensity, short duration work using predominantly anaerobic (without oxygen) energy pathways (Bar-Or, 1987). The results seen in this study, although somewhat difficult to interpret, do offer further evidence that SEALs possess a larger capacity for short bursts of high intensity muscular work.

Using the Cybex testing apparatus as we did in this study, a strength ratio between knee flexor (hamstrings) and knee extensor (quadriceps) of 0.60 to 0.70 is generally considered normal (Fleck & Kraem-, 1988). Although there is controversy on this issue, some researchers and athletic trainers believe that a subnormal ratio may be a contributing factor to joint and soft tissue injury (Boyer, 1975; Grace, 1985; Fleck & Falkel, 1986). Both BUD/S and SEAL groups demonstrated mean strength ratios within the desired range. On an individual basis, however, three BUD/S graduates and three SEALs had ratios less than 0.60 (range .57 to .59) and might be considered at slightly increased risk for injury.

TABLE 4. Muscle endurance and flexibility.

	BUD/S			SEALs		
Attribute	n	Mean	S.D.	n	Mean	S.D.
Muscle Endurance						
Sit-ups (# in 2 min)	39	103.4*	12.0	37	87.0	15.6
Push-ups (# in 2 min)	39	91.8*	13.7	37	80.9	16.3
Pull-ups (max #)	39	15.8*	3.1	37	13.9	4.0
Leg extension work (J)	34	3152.7	400.5	38	3235.6	578.3
Leg flexion work (J)	34	1929.4*	307.2	38	2187.0	569.6
Cycling lactate (mmol/L)	35	6.6*	2.3	39	8.9	2.3
Flexibility						
Sit-reach (cm)	36	12.0*	7.4	32	16.5	8.7

* Significant ($p<.05$) difference between groups.

Jacobs et al. (1983) have shown the blood lactate concentration elicited by the 6-min, 200W cycle test to be highly correlated with both time to exhaustion on an incremental bicycle test, and the work load associated with the onset of blood lactate accumulation (r = -.88 and .97, respectively). Work performed at or above the intensity that produces an accumulation of lactic acid will quickly result in fatigue and incapacitation. Blood lactate values from this test, therefore, may provide an indication of the level of submaximal work that can be performed for an extended period of time. Because of their lower blood lactate scores (see Table 4), BUD/S graduates would be expected to be able to perform prolonged submaximal exercise at higher work loads than could be managed by SEALs. Of course, this test used mainly lower body musculature, and thus speculation on performance capabilities may apply only to similar lower body activities.

A possible confounding factor in the interpretation of the blood lactate results is the influence of muscle glycogen stores. When muscle glycogen stores are depleted, through strenuous exercise and/or inadequate carbohydrate ingestion, blood lactate concentration at a given work load is depressed (Jacobs, 1981). Considering the intensity of their physical training program, it is conceivable that the BUD/S graduates displayed lower blood lactates because of glycogen depletion rather than enhanced endurance capacity. This explanation seems unlikely in that BUD/S lactates reported here were greater than those found by Jacobs et al. (1986) for apparently well trained, but not elite, athletes (4.3 mmol/L). Since BUD/S graduates are presumably similarly well trained, and their mean score is greater than that reported by Jacobs et al., it is unlikely that glycogen depletion depressed the BUD/S blood lactate scores.

Differences in mean BUD/S and SEAL scores for sit-ups, push-ups and pull-ups (Table 4) indicate greater muscular endurance in the BUD/S group. In addition, higher peak VO_2 and lower 1.5-mile run time observed in the BUD/S group (see Table 5) reflect greater cardiovascular endurance capacity. These results, considered together with the blood lactate findings, lead to the conclusion that BUD/S graduates have somewhat greater capacity for prolonged physical activity than do SEALs.

These findings are consistent with the training regimes followed by each group. BUD/S training emphasizes running and calisthenics as physical conditioning tools, whereas SEALs are free to choose their own conditioning programs based upon job experience and personal preference. Responses to the Physical Activity Questionnaire revealed that all BUD/S graduates ran for at least 30 min, at least 3 days a week, while only half of the SEALs followed such a regimen. The mean weekly minutes of running reported by BUD/S and SEAL groups were 530.0 (±217.4) and 110.6 (±102.0), respectively. Likewise, calisthenic exercises including sit-ups, push-ups and pull-ups were performed much more often by BUD/S than SEALs (529.7 ±273.6 versus 123.4 ±109.2 minutes per week).

TABLE 5. Aerobic capacity.

Attribute	BUD/S (n=33) Mean	BUD/S (n=33) S.D.	SEALs (n=32) Mean	SEALs (n=32) S.D.
Aerobic Capacity				
Peak VO_2 (ml/kg·min)	62.4*	3.9	57.7	7.4
Peak ventilation (l/min, BTPS)	159.8*	12.9	148.5	22.2
Peak heart rate (bpm)	187.5	7.9	191.4	10.5
1.5-mile run (min)[a]	8.53*	0.38	9.57	0.79

* Significant (p<.05) difference between groups.

[a] BUD/S (n = 36); SEALs (n = 37).

Both BUD/S and SEALs are quite aerobically fit, as evidenced by comparison of their peak VO_2 scores (Table 5) to values reported in the literature. For both BUD/S and SEAL groups, peak VO_2 is well above those reported for untrained men (44 ml/kg·min, Åstrand & Rodahl, 1977) and for a sample of 64 general Navy men (50.6 ml/kg·min; McDonald, Beckett & Hodgdon, 1988). On the other hand, BUD/S and SEAL groups appear to have less aerobic capacity than elite male long distance runners, cyclists and swimmers (84, 72 and 70 ml/min·kg, respectively, Åstrand & Rodahl, 1977).

To date, the highest oxygen uptakes reported for military personnel have been 58.5 ml/kg·min for British parachutists (Toft cited in Vogel, 1985) and 55 ml/kg·min for U. S. Army Special Forces (Muza, Sawka, Young, Dennis, Gonzalez, Martin, Pandolph & Valeri, 1987). Group means obtained in this study compare quite favorably and may indicate slightly greater aerobic capacity in Navy Special Forces trainees.

TABLE 6. Cold pressor responses.

	BUD/S (n=35)		SEALs (n=38)	
Attribute	Mean	S.D.	Mean	S.D.
Heart Rate (bpm)				
Baseline	61.4	10.3	63.2	7.2
Peak	86.7	9.9	83.7	14.7
Area (bpm x sec)	4125.2	3150.0	2896.4	3156.4
Systolic Blood Pressure (mmHg)				
Baseline	112.5	10.0	112.5	11.2
Peak	141.8	10.3	140.1	11.9
Area (mmHg x sec)	5963.6	3162.7	5542.9	3287.5
1-min rise	22.8	10.6	21.2	12.4
1-min peak	135.3	10.1	133.7	13.4
Diastolic Blood Pressure (mmHg)				
Baseline	72.5	7.3	72.8	10.5
Peak	99.0	9.7	96.1	14.0
Area (mmHg x sec)	5170.3	2738.9	4332.6	3175.0
1-min rise	18.8	9.1	16.6	12.1
1-min peak	91.3	8.8	89.5	13.3

No significant ($p<.05$) differences between groups.

Immersion of the hand in cold water, such as during a cold pressor test, is known to evoke pain, rapid vasoconstriction and rapid rises in blood pressure and heart rate (LeBlanc, 1975; Lott & Gatchell, 1978). Eskimos, who are exposed to very cold temperatures on a regular basis, show attenuated cold pressor responses when compared to control subjects (LeBlanc, 1975). These Eskimos feel less pain, maintain higher skin blood flow and show less rise in blood pressure. LeBlanc (1988) attributes these attenuated responses to "habituation", a damping of the normal response to a stressor. The greater hand blood flow observed in Eskimos may enhance their hand function in the cold (Brown & Page, 1952). In another study, young men who were exposed to cold air (10°C) four hours daily for 21 days showed attenuated heart rate and blood pressure responses to a cold pressor test (Mathew, Purkayastha, Jayashankar & Nayar, 1981). These previous studies indicate that when humans are regularly exposed to cold, there occurs an adaptation (habituation) which may lead to enhanced function and comfort in the cold.

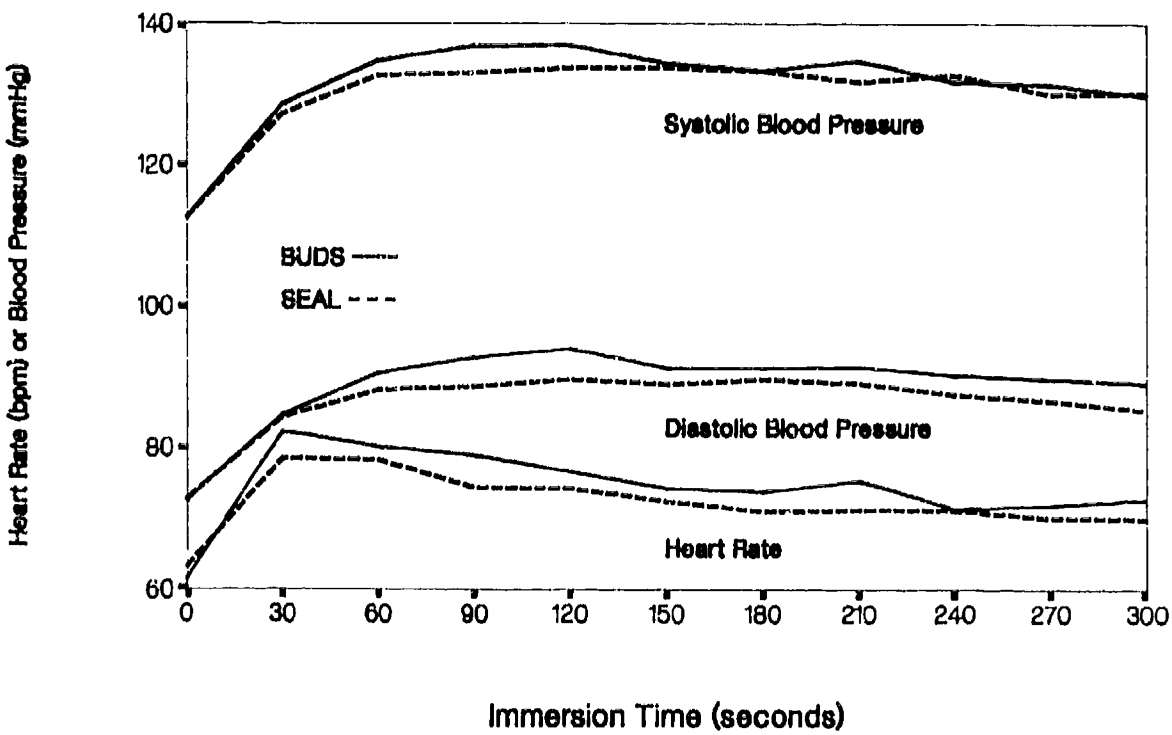

Figure 2. Heart rate and blood pressure responses to 5 minutes of hand immersion in 4° C water. Group means are plotted for BUD/S (n=35) and SEALs (n=38).

Training and operational demands of U. S. Navy Special Forces require frequent exposure to cold water and air. Because of this, it might be expected that BUD/S graduates and SEALs would be, to some degree, adapted to the cold. This study, however, was not designed to determine whether or not these men are cold adapted. Instead, one of its goals was to determine if cold pressor responses are different among the groups and from that make inferences about differences in cold adaptation.

Figure 2 depicts cold pressor heart rate and blood pressure responses for the BUD/S and SEAL groups. No significant differences existed between groups in areas under the curve or in peak responses (Table 6). These findings suggest no difference in cold adaptation of BUD/S and SEAL groups. In each group, however, a wide variety in response curves for individuals was observed and may indicate individual differences in cold adaptation.

When subjects were categorized as either normal or hyperreactor according to the scheme of Hines and Brown (1936) the following results were obtained: The hyperreactor category included 19 BUD/S graduates (54%) and 22 SEALs (58%). A chi-square analysis revealed no significant differences between BUD/S and SEALs in terms of proportions classified as normal or hyperreactor.

Conclusion

BUD/S graduates were found to be leaner than Special Warfare team members, to have slightly less muscle strength and anaerobic power, but greater muscle endurance and aerobic capacity. Both groups had similar responses to a cold pressor test. Differences found here undoubtedly reflect differences between the training and operational environments. Training goals include the need to determine a trainee's capacity to persevere and, therefore, emphasize aerobic and muscle endurance tasks. The operational environment may not make the same demands, as suggested by the differences in physical fitness profiles. It should be recognized that all of these differences are relatively small and not likely to be of consequence in an operational environment. These differences will most likely be resolved by time on the job, but in the meantime, BUD/S graduates will not prove a liability to the operational forces based upon their physical capacities.

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

(U) Candidates for U. S. Navy Special Warfare Sea Air Land (SEAL) teams undergo vigorous training at Basic Underwater Demolition/SEAL (BUD/S) school. Recently, some question has arisen as to whether BUD/S graduates are adequately prepared to become active SEAL team members (SEALs). This study was undertaken to compare BUD/S graduates with SEALs with respect to their physical condition and capacities.

Thirty-nine BUD/S graduates and 48 SEALs were characterized in terms of physical fitness, physique and cold pressor response. BUD/S graduates were found to be leaner than SEALs, to have slightly less muscle strength and anaerobic power, but greater muscle endurance and aerobic capacity. Both groups had similar responses to a cold pressor test.

These differences undoubtedly reflect differences between the training and operational environments, and some consideration must be given to whether the training program needs

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*U.S. Government Printing Office: 1985—507-047 to be modified to change physical fitness outcomes. It should be recognized, however, that these differences in physical fitness are relatively small, and BUD/S graduates appear sufficiently prepared to join the ranks of operational SEALs.